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Procedia Earth and Planetary Science 1 (2009) 989–994

Procedia Earth and Planetary Science

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The 6th International Conference on Mining Science & Technology

Study on hydrocarbon-generation evolution and prediction of favorable exploration areas in Gucheng area of Tarim basin

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Abstract

Lower Ordovician and Cambrian are the good source rocks in Gucheng area compared to the other areas in the east of Tarim Basin. During the early of Caledonian movement after Upper Ordovician deposited, the source rocks of Lower Ordovician quickly went into gate of Hydrocarbon-generation and generated oil & gas. Because the time was so short and buried depth was so deep, the generated oil is not able to be expulsed from source rocks and they had been cracked to generated gas along with source rocks, which Hydrocarbon-generation didn't stop until the source rocks arrived at the dead line of natural gas generated. In the following tectonic movements, the buried depth and temperature didn't measure up to the conditions and the thermal evolution of source rocks had reached the dead line of natural gas generation after Caledonian movement, and no gas could generate. Used SPI, we conclude that the forming pattern of reservoirs is self-generating and self-preserving based on analysis of lithologic characteristics. The favorable exploration areas are located in Paleo-accumulation in the Palaeozoic group, especially dolomite reservoir in Cambrian.

Keywords: gucheng slope break; petroleum system; structural evolution; self-generating and self-preserving

1. Introduction

Gucheng-4 Well lies in the structural high of Gucheng slope break in Tadong raised belt in the east of Tarim Basin. It is about 25 km from the northwest of Gucheng-2, about 106 km from the southwest of Tadong-2 well (Fig. 1). The final depth was 6550 m reaching Cambrian. Silurian, Devonian and Jurassic are lacuna because of Cherchen Fault in the south controls structural evolution of Gucheng area [1-3]. Just as the other areas in the east of Tarim Basin, Cambrian and Ordovician have the high-quality oil-prone source rocks [4-5]. Oil & gas are abundant in the carbonate of Lower Ordovician and Cambrian. Through the analysis of source rock along with structural evolution, we can reconstruct the history of Hydrocarbon generation. To research the potential of oil & gas generation in Gucheng slope break, it can promote the exploration and evaluation of oil and gas in the Lower Paleozoic of Tarim Basin.

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1878-5220
doi:10.1016/j.proeps.2009.09.153

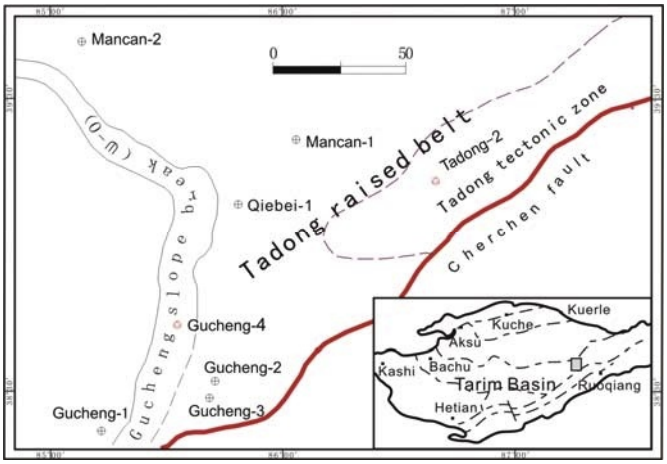

Fig. 1. Regional location map in Gucheng area

2. Source rock evaluation

Multilayer source rocks exist in Gucheng area just as others in the east of Tarim Basin. According to routine analysis of source rock, organic carbon concentration of Carboniferous is 0.06%~0.33%, genetic potential is 0.14 kg/t, kerogen type is Ⅱ-Ⅲ. Because the thickness decreases, the percent of source rocks is only 22.1% (Table 1). Carboniferous has definite oil-generating potential, but we define it as bad oil-generating strata by comprehensive survey and it will be not discussed in this paper.

Table 1. Thickness of Source rock in Gucheng area

Horizon	Thickness (m)	Dark peat				Carbonatite				Generating rock	
		Single layer (m)		Cumulative thickness (m)	Percent (%)	Single layer (m)		Cumulative thickness (m)	Percent (%)	Aggregate thickness (m)	Percent (%)
		max	min			max	min				
Carboniferous	637.5	8	0.5	113.5	17.8	10	0.5	27.5	4.3	141	22.1
Upper-middle Ordovician	2287.5	111	0.5	1840	80.4	-	-	-	-	1840	80.4
Lower Ordovician	768	-	-	-	-	158	0.5	768	100	768	100
Cambrian	308	-	-	-	-	59	0.5	308	100	308	100

In Gucheng area Cambrian and Ordovician are high quality oil-generating strata. Thickness of upper-middle Ordovician is very large, about 2287.5 m, Lower Ordovician is about 768 m, and Cambrian is about 308 m (Table 2). Types of Kerogen are all Ⅰ in marine facies. According to bore specimen, TOC is generality 0.48~11.77, generating potential 0.42~13.58 mg/g, productivity index 0.27~0.50. By solid asphalt to get equivalent vitrinite reflectance [6], we can get thermal evolution of Gucheng-4 because there is no vitrinite in Cambrian & Ordovician formations. Equivalent vitrinite reflectance (Ro) in these formations is mostly more than 2% (Fig. 2), and source rocks are in high maturity condition of dry natural gas.

Table 2. Thermal degradation of source rock in Gucheng area

Well	Depth (m)	Age	Lithology	TOC (%)	S_1 (mg/g)	S_2 (mg/g)	S_3 (mg/g)	S_1+S_2 (mg/g)	P I	HI mg/g. TOC	S_1/TOC mg/g.TOC
Gucheng-4	3944	O_1	silty mud	3.62	3.60	9.98	3.95	13.58	0.27	276	99.45
	5360	O_{2+3}	limestone	0.48	0.42	0.42	1.05	0.84	0.50	88	87.50
	6504.4	O_1	LST DOL	11.77	0.12	0.30	0.74	0.42	0.29	3	1.02

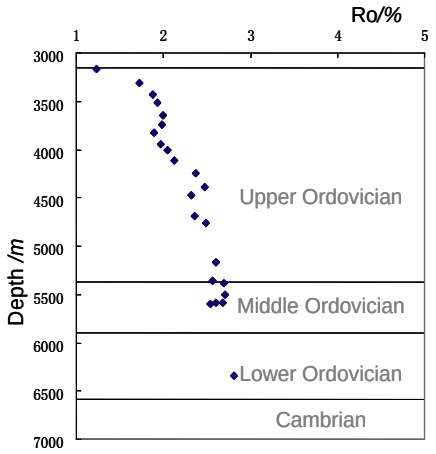

Fig. 2. Thermal evolution of source rock in Gucheng-4

3. Burial history

After multiple phase of tectonic movements, Gucheng area forms today's framework finally. By interpreting seismic cross section and proceeding interval correlation, we recovered the thickness of denudation. Caledonian movement in the east of Tarim Basin was very violent because Paleotethys overtrusted toward Tarim plate SWbW, thickness of overburden was up to 4800 m in Gucheng area. By use of BasinMod1-D we reconstructed the burial history (Fig. 3), and found that source rocks (Cambrian and Ordovician) settled quickly and the maximal buried depth was over 8000 m during Caledonian event. Source rocks began to generate Oil & gas during this period, and after this movement the burial depth and temperature didn't measure up to the conditions of mature. Due to heavy Upper Ordovician deposited, source rocks quickly generated oil, condensate oil, combination gas, dry gas. This is a distinguishing feature in Gucheng area even East Tarim [7].

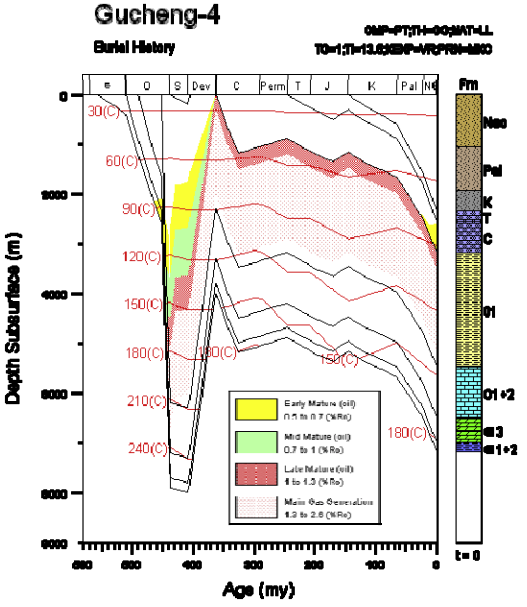

Fig. 3. Burial history and stage of hydrocarbon generation in Gucheng-4 well

4. Hydrocarbon-generation and structural evolution

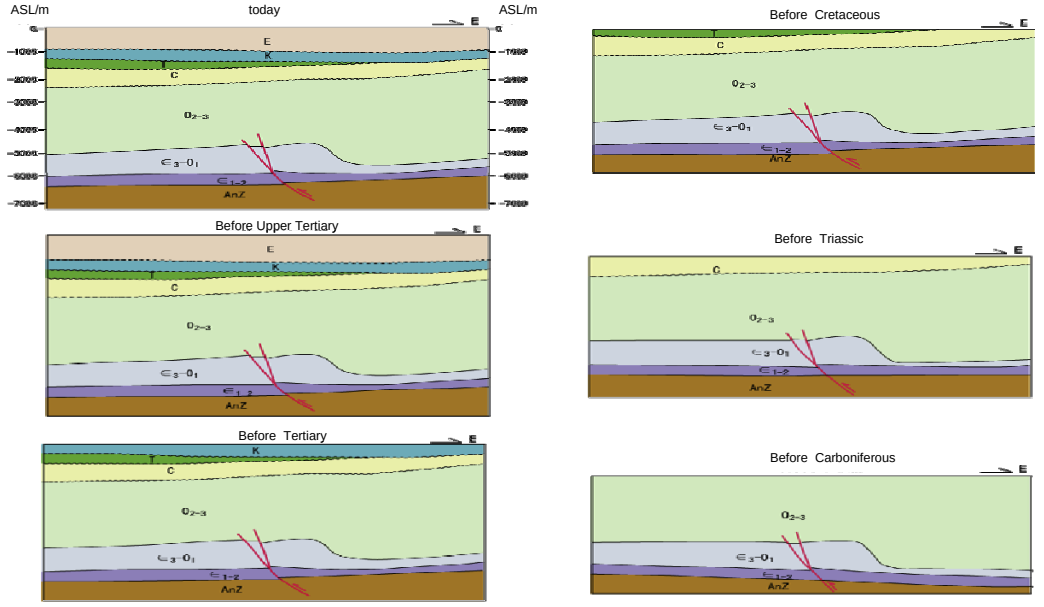

Fig. 4. Structural evolution in latitudinal direction of Gucheng slope breaks from traverse number GC05-401 (From Tarim Oilfields Company)

Tadong raised belt in the east of Tarim Basin underwent multiphase tectonic activity - Caledonian movement [8], Hercynian movement, Indosinian movement, Yanshan movement, Himalayan movement and so on. According to the profiles of tectonic development in Gucheng slope break (Fig. 4), structural feature had a fixed form during Caledonian movement though light tectonic regulated after it. During Caledonian movement, Tadong raised belt was a palaeohigh uplifting southward continuously controlled by Cherchen fault. Deposit of Upper Ordovician was so plenty that strata aggraded quickly during short duration. Silurian, Devonian and parts of Upper Ordovician were eroded away, and the thickness denuded was more than 4800 m. There existed a major exposure level below Carboniferous. There was a higher geothermal Gradient up to 3.1~3.2 °C/100 m during Ordovician Period. Not only source rocks generated hydrocarbon and reached 4.0% during very short dozens of million years quickly, but also crude oil generated from source rocks, generated, cracked gas and solid bitumen[9] (Fig. 5).

During Hercynian movement, Gucheng area uplifted and Palaeozoic strata was eroded away, and Triassic covered over Carboniferous in angular unconformity. Gucheng slope break was adjusted slightly. From Yanshan movement to Himalayan movement, though extensive uplift, but Gucheng area didn't reform essentially. Buried depth and temperature didn't measure up to the conditions and the thermal evolution of source rocks had reached the dead line of natural gas generation after Caledonian movement, and no gas could generate.

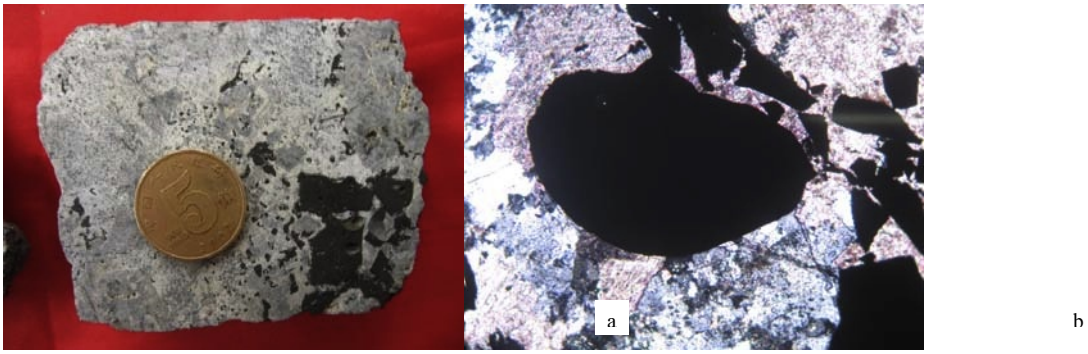

Fig. 5. Bitumen of source rock in Gucheng-4 (a) Calciferous dolomite, brecciform bitumen, Gucheng-4, $\in_3$, 6504.03 m (core); (b) Calciferous dolomite, granulous bitumen, Gucheng-4, $\in_3$, 6504.47 m (flake)

5. Reservoir and period of formation

L.B. Magoon and W.G. Dow put forward a empirical method of judging migration using average SPI [10]. In the system of vertical migration, SPI were divided into low (SPI<5), middle (5≤SPI<15) and high (SPI≥15). In the system of parallel migration, SPI were also divided into low (SPI<2), middle (2≤SPI<7) and high (SPI≥15). The range of SPI is 0.8~1.61 in Gucheng area, the migration of oil & gas was very feeble. Upper Ordovician is a very good capping formation because of large thickness and homogeneousness. If there were not penetrating-formational faults, oil & gas couldn't migrate vertically. Dolomitization was high in Cambrian, so the rocks are good physical property, high porosity and permeability. Cambrian system could be judged as a high quality reservoir. We predict the forming pattern of reservoirs are self-generating and self-preserving finally.

Now, a major method is coupling fluid inclusion in reservoirs with thermal evolution and burial History to presume periods of reservoir formation [11-12]. Due to the homogenization temperature of fluid inclusion in Gucheng area, the major period of reservoir formation was the early of Caledonian movement accompanying deposition of heavy Upper Ordovician and the temperature was 250~300 °C (Fig. 6). The others were the late of Caledonian movement along with uplifting and the temperature was 120~150 °C. The aim of exploration activity next is to find Paleo-accumulation in the Palaeozoic group, especially dolomite reservoir in Cambrian.

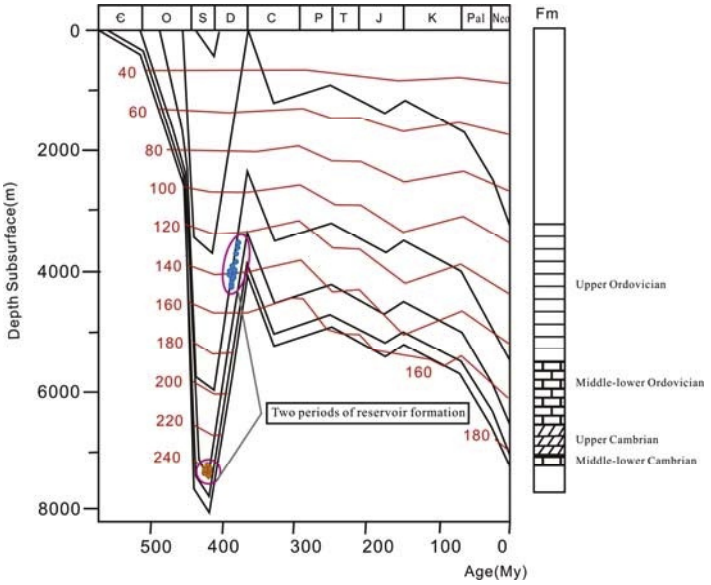

Fig. 6. Two periods of reservoir formation in Gucheng-4

6. Conclusions

From the analysis above, we can conclude:

(1) Burial chron of Upper Ordovician was short and burial depth was deep, oil generated was not able to expulse from source rocks and generated cracked gas along with source rocks.

(2) Structural feature had a fixed form during Caledonian movement, and light tectonic reconstruction happened during later stages. The two periods of reservoir formation were the early and late of Caledonian event.

(3) The aim of exploration activity next is to find Paleo-accumulation in the Palaeozoic group, especially dolomite reservoir in Cambrian system.

Acknowledgements

Grateful acknowledgements are made to Tarim Oilfields Company and its technicians who give us useful data and cores for this study. Thank specially to technical staff who give us beneficial proposes in Lang fang Branch of Research Institute of Petroleum Exploration & Development, PetroChina. The work was supported by the Natural Oil & Gas Stratagem Tap of China.

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